Accred Qual Assur (2008) 13:33–45
DOI 10.1007/s00769-007-0329-7

GENERAL PAPER

The establishment of quality systems in veterinary diagnostic testing laboratories in developing countries: experiences with the FAO/IAEA External Quality Assurance Programme

Axel Colling · Martyn Jeggo · Helder Louvandini · Mamadou Lelenta · Mark Robinson

Received: 20 July 2007 / Accepted: 6 November 2007 / Published online: 4 December 2007

Abstract Quality systems, established to internationally accepted standards, are one mechanism that can assist in evaluations of the sustainability of technology transfer, the proficiency of the user, and the reliability and comparability of data generated, resulting in potential enhancement of laboratory credibility. The means of interpreting existing standards and implementing quality systems in developing country veterinary diagnostic laboratories has become a significant adjunct to the technology transfer element within the Food and Agriculture/ International Atomic Energy Agency, FAO/IAEA programme. The FAO/IAEA External Quality Assurance Programme (EQAP) is given as an example for an initial step towards enhancing the "quality" culture in developing country veterinary laboratories. In 1995 the EQAP began as an effort to assure that test results emanating from laboratories using FAO/IAEA ELISA kits for animal disease diagnosis are valid. For this purpose 15 international external quality-assurance rounds have been performed to date for a variety of animal diseases e.g. Rinderpest, brucellosis, trypanosomosis, and foot-and-mouth disease (FMD). Results indicate that the EQAP is a valuable tool in the assessment of both the results provided by, and use of the ELISA kits provided through, the joint FAO/IAEA programme. Furthermore EQAP can assist laboratory diagnosticians to enhance quality control/quality assurance (QC/QA) procedures for conducting FAO/IAEA ELISAs and to advise on the implementation of similar QC/QA procedures in other laboratory activities. Based on the experiences made during the implementation of the EQAP a proposal for establishing a quality system standard was ratified through the World Organization for Animal Health (OIE) general conference in May 2000. The OIE Standard On Management And Technical Requirements For Laboratories Conducting Tests For Infectious Animal Diseases is based on ISO 17025 and provides a clear formula for establishing quality systems in veterinary diagnostic laboratories world-wide.

Keywords External quality assurance · Proficiency testing · Quality systems · Developing countries · Diagnostic laboratories · Animal health · ELISA

Abbreviations

AbELISA	Antibody enzyme-linked immunosorbent assay
AgELISA	Antigen enzyme-linked immunosorbent assay

A. Colling (✉) · M. Jeggo
Australian Animal Health Laboratory (AAHL) CSIRO Livestock Industries, 5 Portarlington Road, 3219 East Geelong, Victoria, Australia
e-mail: axel.colling@csiro.au

H. Louvandini
Facultade Agronomia e Medicina Veterinaria, Universidade de Brasília Campus Universitário Darcy Ribeiro, Instituto Central de Ciências, Ala Sul Caixa Postal 4.508, CEP: 70.910-970, DF, Brasilia, Brazil

M. Lelenta
Animal Production Unit, FAO/IAEA Agriculture and Biotechnology Laboratory Agency's Laboratories, 2444 Seibersdorf, Austria

M. Lelenta
International Atomic Energy Agency, Wagramer Strasse 5, P.O. Box 100, 1400 Vienna, Austria

M. Robinson
National Program Leader for Animal Agrosecurity, USDA Cooperative State Research, Education, and Extension Service, 800 Ninth Avenue, Room 3153, Washington, DC 20024, USA

cELISA	Competitive enzyme-linked immunosorbent assay
EQAP	External Quality Assurance Program
FAO	Food and Agriculture Organization
FMD	Foot-and-mouth disease
GATT	General Agreement on Tariffs and Trade
GREP	Global Rinderpest Eradication Campaign
IAEA	International Atomic Energy Organisation
iELISA	Indirect enzyme-linked immunosorbent assay
IQC	Internal quality control
ISO	International Organisation for Standardization
OECD	Organization for Economic Co-operation and Development
OIE	World Organization for Animal Health
PARC	Pan African Rinderpest Eradication Campaign
PCR	Polymerase chain reaction
QA	Quality assurance
QC	Quality control
QM	Quality management
SOP	Standard operating procedure
WAVLD	World Association of Veterinary Laboratory Diagnosticians
WTO	World Trade Organization

Introduction

Ministries of agriculture determine policy, make decisions and take actions affecting the livestock sector, based in part on information provided by national veterinary diagnostic testing laboratories. However few developing countries have mechanisms for recognition of quality management (QM) or technical competence of these laboratories. For example Australia has an ISO 17025-based veterinary laboratory accreditation scheme in place and is making it available to other countries in Asia on a cost-recovery basis, but many countries in Asia have no such mechanism or recognition process.

An emerging challenge, in part in response to the World Trade Organization (WTO) Sanitary Phytosanitary Agreement, is to make the organization and operations of national-level veterinary services, including diagnostic testing laboratories, transparent to outside observers so that the quality and comparability of animal health data and programmes can be evaluated [1, 2]. Historically, the World Organization for Animal Health (OIE) has been a focus of information gathering and dissemination for animal health trade issues. Following the completion of the Uruguay round of General Agreement of Trade and Tariffs (GATT) and formation of the World Trade Organisation (WTO) the OIE was given the task of continuing this process of livestock trade facilitation. One major recent breakthrough was that OIE has taken a more standardized approach for the validation, certification, and registration of diagnostic tests by identifying the purpose for which diagnostic tests are used and also the development of a template which assists in providing information about critical assay performance parameters in a standardized format.

A variety of processes have been developed world-wide to recognize quality assurance (QA) systems in the manufacturing, production, and service sectors, as well as the technical competence of testing laboratories. In particular, the ISO/IEC 17025 [3] forms the basis of many national standards for recognition of the competence of calibration and testing laboratories while the Organization of Economic Co-operation and Development, OECD Principles of Good Laboratory Practice (OECD-GLP) [4] are used internationally as a basis for determining a laboratory's compliance with safety study guidelines. It is noted that an increasing number of government laboratories have achieved both the equivalent of ISO 17025 Accreditation and OECD Compliance recognition. OIE's interpretation of ISO 17025 is available as "OIE quality standard and guidelines for veterinary laboratories: Infectious diseases" [5].

The FAO/IAEA External Quality Assurance programme (EQAP) as a starter to establish quality systems

FAO/IAEA support in the area of animal health is focussed on enhancing the ability of national veterinary authorities in developing countries to accurately diagnose livestock diseases of major importance using nuclear and related technologies, such as enzyme-linked immunosorbent assays (ELISA), and to help monitor the effectiveness of national and regional disease control and eradication strategies. This is done through provision of advice to member state veterinary authorities concerning the development of appropriate sampling or research strategies coupled with FAO/IAEA-led collaborative development, adaptation, standardization, evaluation, and provision of quality-controlled and validated ELISA kits and the components necessary for diagnostic application of molecular diagnostics such as the polymerase chain reaction (PCR) [6, 7]. Additional features of FAO/IAEA animal health support include provision of relevant laboratory equipment and training of counterpart scientists and technicians in the use of the equipment and standardized assays, co-ordination of EQA programmes to monitor the proficiency of the assay performer, and assistance with the interpretation of these results within the context of on-going disease control and eradication efforts.

The development and adaptation of immunoassays and molecular techniques for use in national veterinary laboratories in developing countries, the standardization of equipment, working protocols, and interpretation of test results, and the evaluation of assay reliability under the conditions found in such laboratories are complex and time-consuming. In many cases the responsibilities between the kit producer and end user are not clear and the situation is compounded by the number and diversity of diagnostic kits used within the framework of the FAO/IAEA Animal Production and Health Subprogramme, the variability of working conditions and staff expertise at laboratories in developing countries, and the stressful conditions that the kit components suffer in transit to counterpart laboratories and subsequent use [8]. Parameters such as ruggedness and robustness play an important role in the usefulness of the kit but are difficult to quantify in statistical terms.

The FAO/IAEA External Quality Assurance Programme (EQAP) for animal disease diagnosis began as an effort to quality assure the monitoring of the effectiveness of national mass vaccination programmes as part of the Pan African Rinderpest Eradication Campaign (PARC). Proficiency test panels, composed of 40 "unknown" serum samples, were sent to participating laboratories yearly to measure their abilities to correctly use the ELISA to distinguish between samples that were positive or negative for Rinderpest antibodies generated by vaccination. From this beginning, the EQAP has grown into an effort to measure general and specific components of FAO/IAEA counterparts' quality systems and provide assurance to outside observers that the use of FAO/IAEA diagnostic ELISAs were within established control limits and the test results and diagnostic interpretations reliable [9, 10].

A major objective of the EQAP was to establish a network of national veterinary diagnostic testing laboratories that are recognized for their achievements in establishing quality systems and their proficiency in the use of specific diagnostic assays. This network facilitated the exchange of diagnostic and epidemiological information and, in the current atmosphere of international and regional trade agreements, increased the transparency required for international trade of livestock and livestock products.

The EQAP for animal disease diagnosis was organized to consist of three components:

1 a process for measuring test proficiency by interlaboratory comparison;
2 a process to report on the internal quality control (IQC) data for FAO/IAEA ELISAs used in the counterpart laboratory; and
3 a questionnaire to gather information about the counterpart laboratory's infrastructure, QC practices, staff qualifications, and operations.

The objectives of the EQAP were:

1 to determine the user's quality system status and assay proficiency;
2 to enhance the user's QA awareness and culture;
3 to provide reference data to help identify and solve systematic and random errors;
4 to provide an organized and transparent mechanism to enhance the national and international credibility of the user's laboratory; and
5 to develop reference data for the assessment of new FAO/IAEA diagnostic assay performance in the field.

In addition, the data developed through the EQAP can be used from a programmatic perspective as baseline data for:

1 the development of appropriate intervention strategies;
2 monitoring implementation; and
3 evaluation of impact during and after the conclusion of the project.

Laboratories who successfully participated in the EQAP were formally granted "FAO/IAEA Recognition".

Scope of the EQAP

The EQAP focussed on the diagnosis of the major OIE-listed infectious livestock diseases using ELISA technology. The programme began with the FAO/IAEA competitive ELISA (cELISA) for Rinderpest, and progressed to include the indirect ELISA (iELISA) for brucellosis, the antigen ELISA (AgELISA) for trypanosomosis, the antigen and antibody ELISAs (AgELISA and AbELISA, respectively) for foot-and-mouth disease (FMD), and occasionally, other assays of importance to the Animal Production and Health Subprogramme.

Implementation and results 1995–1999

During the period 1995–1999 a total of 15 EQA rounds were performed. Four rounds for the FAO/IAEA Rinderpest competitive antibody ELISA were completed (23, 29, 29, and 29 participating laboratories, respectively) [11–14]. Seven rounds were completed with the indirect brucellosis ELISA (31, 35, 39, 33, 32, 32, and 29 participating laboratories, respectively) [15–21]. One round for the trypanosomosis antigen ELISA was completed (16 participating laboratories) in 1996 [22] and one round with an antibody ELISA was done in 1998 [23]. One round for the FMD antigen and antibody ELISA with 10 participants in South East Asia was completed in 1996. No interim report

was produced for this round but results were communicated on an individual basis. A second round with the same participants was performed with the FMD antibody ELISA in 1998 and a comprehensive interim report was produced [24, 25]. Additional rounds for the trypanosomosis antigen ELISA and FMD antigen ELISA were not conducted because programmatic support for the trypanosomosis antigen ELISA was discontinued and the preparation and interpretation of proficiency test panels for the FMD antigen ELISA proved to be more expensive and difficult than could be handled with restricted programme resources. It was recommended that once the EQAP was completed the organization and implementation of interlaboratory proficiency test rounds would be transferred to regional centres of excellence, e.g. OIE/FAO reference or collaborative laboratories. Successful participation in proficiency testing rounds are essential requirements to comply with international quality standards such as ISO/IEC 17025:2005, General requirements for the competence of testing and calibration laboratories or OIE standard on management and technical requirements for laboratories conducting tests for infectious animal diseases.

Participants of EQAP between 1995 and 1999 are summarized in Tables 1 and 2 and Figs. 1 and 2.

To date, the participation in proficiency testing rounds represents a learning process for both the counterparts and the FAO/IAEA staff.

The results for the Rinderpest rounds showed that the majority of participating laboratories, particularly those involved with the Pan African Rinderpest Eradication Campaign (PARC), have a high level of proficiency in the use of the competitive antibody ELISA. This information has been communicated to the organizers of PARC, the Global Rinderpest Eradication Programme (GREP), the OIE, and the FAO. Comprehensive interim reports were produced for each round and forwarded to the participants, and summaries, conclusions, and recommendations, e.g. continued problems in the maintenance and calibration of equipment, were addressed at international fora and conferences e.g. World Association of Veterinary Laboratory Diagnosticians and World Organization for Animal Health.

Results of the brucellosis ELISA rounds have been less clear-cut, although very informative. The positive/negative threshold for the brucellosis indirect antibody ELISA must be established by the end-user for each laboratory, as opposed to the threshold for the Rinderpest competitive antibody ELISA, which is established for all users at 50% inhibition. The brucellosis ELISA thresholds vary widely

Table 1 FAO/IAEA external quality assurance programme implementation 1995–1999

ELISA	Reports					Region, year, and number of participants
	1995	1996	1997	1998	1999	
Rinderpest	RP95a	RP96a	RP97a	RP98a		Africa and West Asia
competitive antibody ELISA						No. of participating laboratories: 1995 23; 1996 29; 1997 29; 1998 29
Brucellosis	BRA95a	BRA96a	BRA97a	BRA98a	BRA99a	World-wide
indirect antibody ELISA				BRA98b	BRA99b	No. of participating laboratories: 1995a: 31; 1996a:35; 1997a:39, 1998a:33, 1998b: 32, 1999a:32, 1999b:29
Foot-and-mouth		–[a]		FMD98a		South East Asia
antigen ELISA						No. of participating laboratories: 1996:10; 1998:10
antibody ELISA						
Trypanosomosis		TRYP96a		– [b]		Africa
antigen ELISA						The trypanosomosis antigen ELISA (Tryp96a) included three antigen ELISAs for (*T. brucei*, *T. congolense* and *T. vivax*).
antibody ELISA						Number of participating laboratories: 1996:16.
						The trypanosomosis antibody ELISA 1998 was carried out with denatured *T. congolense* Ag precoated plates.
						Number of participating laboratories
						1998:6

Abbreviations for interim reports for Rinderpest, brucellosis, trypanosomosis and foot-and-mouth disease: RP95a, RP96a, RP97a, RP98a, BRA95a, BRA96a, BRA97a, BRA98a, BRA98b, BRA99a, BRA99b, TRYP96a, FMD98a

[a] No interim report but results are communicated on an individual basis

[b] No interim report but results published as paper

Table 2 Participants in EQAP 1995–1999

Rinderpest	
Benin	Laboratoire de Diagnostic Veterinaire, Project Developpement Elevage Bovin Borgou
	B.P. 23, Parakou
Burkina Faso	Laboratoire National d'Elevage
	B.P. 7026
	Ouagadougou
Central African Republic	Direction de la Santé Animale et de Recherches Appliquees
	B.P. 1509
	Bangui
Cameroon	Laboratoire National Vétérinaire
	B.P. 503
	Garoua
Chad	Laboratoire de Recherche, Vétérinaires et Zootechniques de FARCHA
	B.P. 433
	N'Djaména
Cote d'Ivoire	Laboratoire de Pathologie Animale
	B.P. 206
	Bingerville
Egypt	Animal Research Institute
	Nadi El-Seid Street
	Dokki
	Cairo
Eritrea	Head, Veterinary Services Division
	P.O. Box 1162
	Asmara
Ethiopia	National Animal Health Research Centre, Sebeta, Ministry of Agriculture
	P.O. Box 9765
	Addis Ababa
Gambia	Central Veterinary Laboratories
	P.O. Box 553
	Banjul
Ghana	Central Veterinary Laboratory, Dept. of Vet. Services, Ministry of Agriculture
	P.O. Box 97, Tamale
	Department of Veterinary Services
	Ministry of Agriculture
	P.O. Box M. 161
	Accra
Guinee	Direction Nationale de l'Elevage
	Projet de Restructuration du Secteur Elevage
	Laboratoire Veterinaire de Conakry
	B.P. 559
	Conakry
Iran	I.R. Iran's Veterinary Organization
	Directorate of Quarantine
	Ministry of Jihad -E- Sazandegi
	Tehran
Iraq	Director of Veterinary State Commission
	Bagdad
Jordan	Ministry of Agriculture, Veterinary Department
	P.O. Box 2395
	Amman
Kenya	Central Veterinary Laboratories
	P.O. Kabete
	Nairobi
Kuwait	The Public Authority And Fish Resources
	Animal Health Department
	Safat 13075
Lebanon	Agriculture Research Institute
	Fanar Laboratory
	Beirut
Mali	Laboratoire Central Vétérinaire du Mali
	B.P. 2295
	Bamako
Mauritania	Ministère du Developpement Rural
	C.N.E.R.V.
	B.P. 167
	Nouakchott (R.I.M.)
Niger	Laboratoire Central de l'Elevage
	LABOCEL
	B.P. 485
	Niamey
Nigeria	Virology Division
	National Veterinary Institute
	Vom
	Jos Plateau State
Saudi Arabia	Animal Resources and Husbandry
	Ministry of Agriculture and Water, Riyadh
Senegal	ISRA/LNERV
	B.P. 2057
	Dakar-Han
	Dakar
Sudan	Labs. & Vet. Res. Administration (Soba)
	P.O.B. 8067 El-Amarat
	Khartoum
Syria	Ministry of Agriculture and Agrarian Reform, Directorate of Animal Health
	Central Veterinary Laboratory
	Damaskus

Table 2 continued

Rinderpest	
Tanzania	Animal Disease Research Institute P.O. Box 9254 Dar es Salaam
Turkey	General Directorate Protection and Control, Akay Cad no 3 06100, Bakanliklar, Ankara
Uganda	Livestock Health Research Institute (LIRI) P.O. Box 96 Tororo
Uzbekistan	Main State Veterinary Department Ministry of Agriculture Tashkent
Yemen	Ministry of Agriculture, Animal Health Directorate, Control Veterinary Laboratory P.O. Box 13449 Sana'a
Brucellosis	
Algeria	Centre de Developpement des Techniques Nucleaires (CDTN) Laboratoire de Zootechnie 02 Bd Frantz Fanon BP 1017 Alger-Gare
Argentina	GELAB, SEANASA, Martinez Dept. de Brucellosis Av. Fleming 1653 1640 Martinez Instituto de Bacteriología Centro de Investigación en Ciencias Veterinarias Instituto Nacional de Tecnología Agropecuaria INTA C.C.77 1708 Morón, Buenos Aires Instituto Nacional de Tecnología Agropecuaria E.E.A. Bariloche - C.C. 277 8400 Bariloche
Bolivia	Laboratorio de Investigación y Diagnóstico Veterinario, LIDIVET Avenida Ejército Nacional No 153 Casilla No 29 Santa Cruz Bolivia

Table 2 continued

Brucellosis	
Brazil	Instituto de Pesquisas Veterinárias "Desidério Finamor" (IPVDF) Caixa Postal 2076 90.001-970 Porto Alegre/RS Laboratorio de Reproduçao Animal Centro de Ciencias Biologicas Campus Universitario do Guamá Universidade Federal do Para, UFPA 66.050 Bélem, Pará
Burkina Faso	Laboratoire National d'Elevage BP 7026 Ouagadougou
Cameroon	Laboratoire National Veterinaire B.P. 503 Garoua
Chile	Servicios Agrícolas y Ganaderos Laboratorio Regional Osorno Mackenna 674 Osorno
Colombia	Instituto Colombiano Agropecuario ICA-CORPOICA Centro de Investigaciones en Salud y Producción Pecuaria - CEISA Avenida El Dorado No. 42-42 Santafé de Bogotá D.C.
Costa Rica	Tropical Disease Research Program (PIET) School of Veterinary Medicine Universidad Nacional Heredia
Cote d'Ivoire	Laboratoire de Pathologie Animale B.P. 206 Bingerville
Cuba	Instituto de Medicina Veterinaria Laboratorio Central de Diagnóstico Veterinario Calle 12 entre 15 y 17 Vedado, Plaza Ciudad Habana Fax 537-332666
Congo	Kinshasa Central Veterinary Laboratory, POB 8842 Kinshasa/Gombe
Egypt	Animal Research Institute Nadi El-Seid Street Dokki Cairo

Table 2 continued

Brucellosis	
El Salvador	Centro de Desarrollo Ganadero
	Cantón El Matazano - Soyapango
	El Salvador C.A.
	San Salvador
Ethiopia	National Animal Health Research Centre, Sebeta
	Ministry of Agriculture
	P.O. Box 9765
	Addis Ababa
Ghana	Central Veterinary Laboratory, Dept. of Vet. Services, Ministry of Agriculture
	P.O. Box 97, Tamale
	Department of Veterinary Services
	Ministry of Agriculture
	P.O. Box M. 161
	Accra
Kenya	Central Veterinary Laboratories
	P.O. Kabete
	Nairobi
Madagascar	Department of Veterinary Research (FOFIFA)
	Ministry of Scientific and Technological
	Research and Development
	B.P. 4
	Antananarivo 101
Mali	Laboratoire Centrale Vétérinaire
	B.P. 2295
	Bamako
Mauritania	Ministère du Developpement Rural
	C.N.E.R.V.
	B.P. 167
	Nouakchott (R.I.M.)
Mexico	Instituto Nacional de Investigaciones Forestales y Agropecuarias - INIFAP
	CENID Microbiología
	Km. 15 1/2 Carretera Mexico
	Toluca
	C.P. 05110
	Universidad Autónoma de Yucatán
	Facultad de Medicina Veterinaria y Zootecnia
	Apdo. Postal 4116 Itzímna
	C.P. 97000, Mérida
	Yucatán
Mongolia	Veterinary Research Institute
	Zaisan
	Ulanbaataar 210153

Table 2 continued

Brucellosis	
Myanmar	Livestock Breeding and Veterinary Department,
	Insein,
	Yangon 11011
Namibia	Central Veterinary Laboratory
	P. Bag. 13187
	Windhoek
Nicaragua	Dirección de Sanidad Animal
	Centro Nacional de Diagnóstico e Investigaciones Veterinarias
	Ministerio de Desarrollo Agropecuario y Reforma Agraria
	Managua
Niger	Laboratoire Central de l'Elevage
	B.P. 485
	Niamey
Nigeria	Virology Division
	National Veterinary Institute
	Vom
	Jos Plateau State
Panama	Ministerio de Desarrollo Agropecuario
	Dirección Nacional de Sanidad Animal Agropecuaria
	Panama City
Paraguay	Servicio Nacional de Salud Animal
	Casilla de Correo N 1110
	Km. 10 1/2 Ruta Mcal. Estigarribia
	San Lorenzo - Asunción
Peru	Universidad Nacional de San Marcos
	Facultad de Medicina Veterinaria
	Apdo. 03-5137
	Salamanca, Lima
	SENASA
	Av. La Molina S/N
	Distrito La Molina
	Ministerio de Agricultura
	Servicio Nacional de Sanidad Agraria
Senegal	LENERV
	B.P. 2057
	Dakar-Han
	Dakar
Sudan	Labs. & Vet. Res. Administration (Soba)
	P.O.B. 8067 El-Amarat
	Khartoum
Tanzania	ADRI-TEMEKE
	P.O. Box 9254
	Dar-es-Salaam

Table 2 continued

Brucellosis	
Tunisia	Institut de la Recherche Vétérinaire de Tunis
	Head Virology Laboratory
	20 Rue Djebel Lakhadhar
	La Rabta
	1006 Tunis
Uganda	Livestock Health Research Institute
	P.O.B. 96
	Tororo
UK	Central Veterinary Laboratory
	New Haw, Weybridge
	Surrey KT15 3NB
	United Kingdom
Uruguay	Dirección de Laboratorios Veterinarios - DILAVE
	"Miguel C. Rubino", Dept. de Parasitología
	Min. de Ganadería, Agricultura y Pesca
	Ruta 8 Km. 17.5
	CC. 6577, Montevideo
Zambia	Central Veterinary Laboratories
	Balmoral, Lusaka
	POB 31966
Trypanosomosis	
Burkina Faso	Centre International de Recherches
	Dévéloppement sur l' élévage en zone sub-humide (CIRDES)
	CRTA 01 BP 454
	Bobo Dioulasso 01
Cameroon	Laboratoire National Vétérinaire de Bokle
	B.P. 503
	Garoua
Côte d'Ivoire	Laboratoire Central de Pathologie Animale (LCPA)
	B.P. 206
	Bingerville
Ethiopia	National Tsetse and Trypanosomiasis Investigation and Control Coordination Centre (NTTICC)
	P.O. Box 113
	Bedelle, Illubabor
Ghana	Tsetse and Trypanosomiasis Unit
	Central Veterinary Lab.
	P.O.B. 97
	Pong-Tamale, N/R

Table 2 continued

Trypanosomosis	
Kenya	Kenya Trypanosomiasis Research Institute
	P.O. Box 362
	Kikuyu
Mali	Laboratoire Central Vétérinaire du Mali
	B.P. 2295
	Bamako
Nigeria	National Veterinary Research Institute
	Parasitology Division
	P.M.B. 01
	Vom, near Jos
	Plateau State
Senegal	Institut Sénégalais de Recherches Agricoles
	Laboratoire National de l'Elevage et de Recherches Vétérinaires - ISRA/LNERV
	B.P. 2057
	Dakar-Han, Dakar
Sudan	Faculty of Veterinary Science
	University of Khartoum
	P.O. Box 32
	Khartoum North
The Gambia	International Trypanotolerance Centre (ITC),
	Disease Research Unit of the ITC
	P.M.B. 14
	Banjul
Uganda	Livestock Health Research Institute
	P.O. Box 96
	Tororo
United Republic of Tanzania	DLDZ/FAO/IAEA Tsetse Eradication Project
	URT/5/016
	P.O. Box 159,
	Zanzibar
	Animal Disease Research Institute
	P.O.B. 9254
	Dar-es-Salaam
Zambia	Central Veterinary Research Institute
	P.O.B. 33980
	Lusaka

Table 2 continued

Trypanosomosis	
Zimbabwe	Central Veterinary Laboratory Diagnostic and Research Branch P.O. Box CY551 Causeway - Harare
Foot-and-mouth disease	
Bangladesh	Bangladesh Livestock Research Institute Animal Health Division Savar Dairy Farm 1341 Savar, Dhaka
Cambodia	National Veterinary Diagnostic Laboratory Department of Animal Health and Production Ministry of Agriculture, Forestry, Fisheries and Wildlife Phnom Penh
Hong Kong	Agriculture & Fisheries Department Canton Road Government Offices
Lao PDR	Department of Livestock and Veterinary Service Ministry of Agriculture/Forestry Vientiane
Malaysia	Regional Veterinary Laboratory Kuban Kerian 16150 Kota Bharu Kelantan
Myanmar	Livestock Breeding and Veterinary Department Foot-and-Mouth Division Insein Yangon 11011
Philippines	Philippine Animal Health Centre Bureau of Animal Industry Visayas Avenue, Diliman Quezon City Metro Manila
Sri Lanka	Department of Animal Health and Production P.O. Box 13 Peradeniya
Thailand	Foot and Mouth Disease Centre Division of Veterinary Biologics Department of Livestock Development Pakchong Nakhonratchasima, 3010
Vietnam	Department of Animal Health National Veterinary Diagnostic Centre Phuong Mai Dong Da Hanoi

among laboratories, because of breed variations, vaccination policies, use of different vaccines and other confounding local influences [26]. Therefore, qualitative responses to a common set of unknown samples varied depending on the threshold used by any one laboratory. When the qualitative responses were evaluated alone, the proficiency in use of this assay was low (83% correct diagnostic interpretations among responders). However, when the quantitative data were normalized to a common threshold value, the "true" assay proficiency was much higher (96% correct diagnostic interpretations). This phenomenon illustrated that proficiency test organizers must be careful when establishing the criteria for evaluations of test panel responses. These results have also been communicated to the World Organization for Animal Health.

The rounds for the trypanosomosis antigen ELISA and the FMD antigen and antibody ELISAs have been of less immediate value than those described above. FAO/IAEA support for the trypanosomosis antigen ELISA was stopped shortly after the 1996-round was finished, so the exercise served to introduce the counterparts to fundamental QA concepts and FAO/IAEA evaluation techniques, but not much more.

The foot-and-mouth disease ELISA proficiency testing round was conducted during the period that the ELISAs were first being introduced into the participating laboratories, so it served to provide information on the success of initial implementation, but did not provide a fair test of established proficiency. A follow-up round with the FMD antibody ELISA was undertaken in 1998. Comparing the results from the first round in 1996 and second round in 1998 it was concluded that the number of responses and the quality of results from external and internal controls had improved considerably.

Lessons learned

The major emphasis of the EQAP has been on proficiency testing and education of counterparts to use and analyse QC data to better monitor the precision of their test. Information derived from the questionnaire and analysis of reported internal QC data have represented adjuncts to a core programme of unknown sample analysis, but the criteria for "Recognition", as specified by the 1994 Consultants' Report [9], did not include specific requirements for QM or laboratory performance with respect to assay control, e.g. analysis and documentation of internal QC data. Rather, general attention to improvement and documentation in these areas was encouraged, but the primary measure of successful EQAP participation for "Recognition" was correct identification of the unknown samples of the proficiency test panel.

It has become clear that the strong correlation between proficiency testing and programmatic "Recognition" is

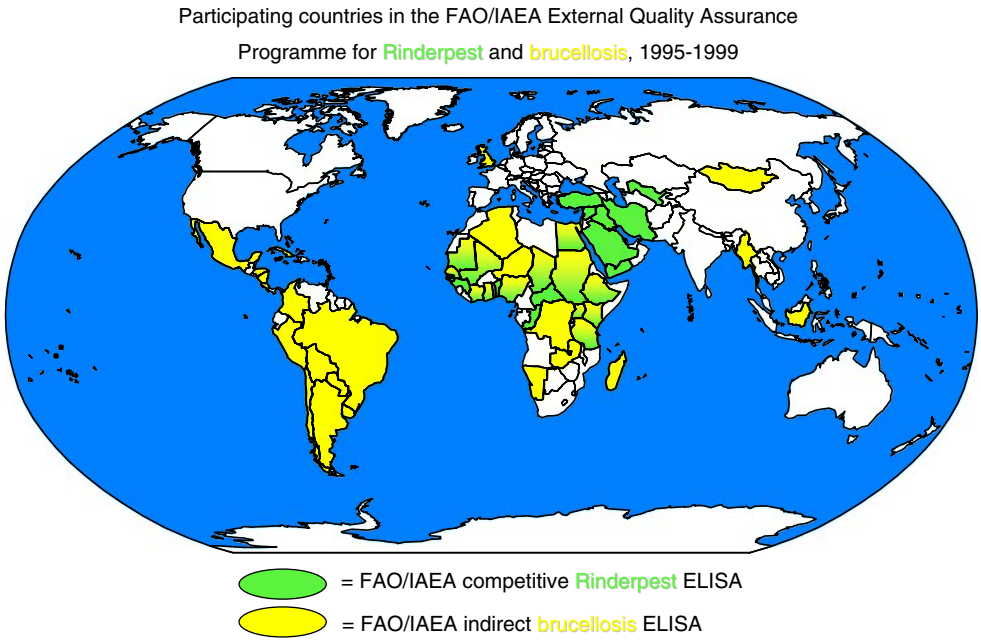

Fig. 1 Participating countries in the FAO/IAEA EQA programme with the Rinderpest and brucellosis ELISA 1995–1999

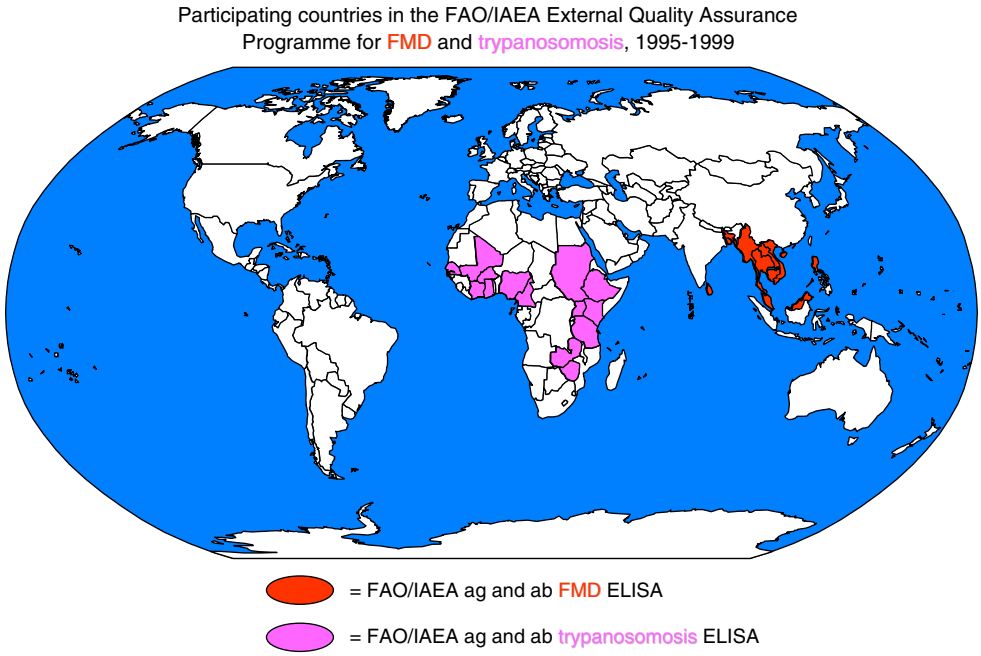

Fig. 2 Participating countries in the FAO/IAEA EQA programme with the foot-and-mouth disease (FMD) and trypanosomosis ELISA 1995–1999

inappropriate. It has been observed that performance on an annual or biannual proficiency test panel does not necessarily provide an accurate picture of the day-to-day quality of operations of the counterpart's laboratory. Additionally, many of the laboratories have not complied with the requirements to provide updated quality manual information or recent internal QC data with each proficiency test round because they did not understand the benefits to be gained from this exercise or did not consider these to be important elements of the EQAP.

To remedy this situation, the following revised definitions and criteria for FAO/IAEA Recognition have been developed [27].

Definition of FAO/IAEA Recognition

FAO/IAEA Recognition was programmatic in nature and given retrospectively for a defined period of time. It was explicit recognition of an FAO/IAEA Coordinated

Table 3 Criteria that must be fulfilled to achieve FAO/IAEA Recognition

Provide evidence of a quality system	
A quality manual including as a minimum:	a statement of laboratory mission
	a description of the laboratory organization
	staff qualifications
	general operational and laboratory procedures
	safety procedures
	standard operating procedures for routine assays
	work instructions for routine procedures
Documentation of QC procedures:	inventory controls
	equipment calibration checks
	approved workplans for non-routine activities
Provide evidence of the maintenance of assay control including:	routine use of IQC samples where appropriate
	routine use of control charts where appropriate
	routine use of standard curves where appropriate
	maintenance of documentation for all controls
Participate regularly and successfully in FAO/IAEA proficiency test rounds:	respond to questionnaire/update
	supply IQC data electronically and/or in control chart form
	correctly interpret unknown samples within pre-established limits

Table 4 Number of FAO/IAEA-recognized laboratories during 15 EQA rounds, 1995–1999

Type of ELISA	Number of laboratories participating	Recognized laboratories	Provisionally Recognized laboratories
Ind. Brucellosis ELISA99b	29	7	4
Ind. Brucellosis ELISA99a	32	7	4
Ind. Brucellosis ELISA98b	32	7	5
Ind. Brucellosis ELISA98a	33	4	7
Ind. Brucellosis ELISA97a	39	6	9
Ind. Brucellosis ELISA96a	35	Na	Na
Ind. Brucellosis ELISA95a	31	Na	Na
Competitive Rinderpest ELISA98a	29	2	12
Competitive Rinderpest ELISA97a	29	5	8
Competitive Rinderpest ELISA96a	29	Na	na
Competitive Rinderpest ELISA95a	23	Na	na
Trypanosomosis ELISA95a and 98	16	Na	na
Ab foot-and-mouth disease ELISA98a	10	Na	na
Ag foot-and-mouth disease ELISA96a	10	Na	na

Na, not applicable

Research Project (CRP) or Technical Cooperation Project (TCP) Counterpart's success in meeting FAO/IAEA criteria for good laboratory QM and operations (see criteria below), as well as successful participation in regular proficiency tests for specific FAO/IAEA animal disease ELISAs.

FAO/IAEA Recognition did not constitute certification, accreditation, or recognition of compliance as defined by the International Organization for Standardization (ISO), the Organization for Economic Cooperation and Development (OECD), or similar international, regional, or national organizations. In addition, it was not an explicit guarantee of a laboratory's future performance.

Criteria for FAO/IAEA Recognition

FAO/IAEA recognition could be granted only to those laboratories that had current or recent FAO/IAEA or IAEA project involvement and those that voluntarily subscribed to the criteria of the FAO/IAEA EQA, the latter on a case-by-case basis as resources permitted (Table 3).

Monitoring and evaluation

The EQAP assisted participants in the development of a quality-management system and in the use and documentation of internal QC data. Standard formats for the presentation of this information were supplied and their use was encouraged. Once quality elements were in place and in use, provision of evidence to meet criteria as quoted above was generated on a regular basis, but not less than

once per year, to achieve or maintain "Recognition" status (see below) [27].

The evidence to meet criteria above could be provided through a number of mechanisms. It could be communicated by e-mail, fax, or post in a timely manner to the EQAP Coordinator or relevant FAO/IAEA Technical Officer. It was made available to the FAO/IAEA Technical Officer during official visits to the counterpart laboratory, if requested.

EQA status

Participation in the EQAP was on a confidential basis. Comprehensive reports were issued anonymously with respect to the participants, and the recognition status of any participant was disclosed only with the permission of the participant.

FAO/IAEA Recognition was granted following the verification by the EQAP Coordinator of compliance with criteria above plus successful participation in two proficiency test rounds. Continued successful participation resulted in continued Recognition. Lack of participation in more than one round resulted in losing Recognition status.

Because the objective of this programme was to assist veterinary laboratories to improve their test performance and reliability, the primary focus was to establish credible quality management and operating systems and establish sustainable proficiency in the application of FAO/IAEA diagnostic assays, and to provide a bridge between whatever level of quality system participating laboratories had in place and potential future formal certification or accreditation to internationally-accepted standards. In addition, the unique problems facing these laboratories and any other extenuating circumstances affecting a laboratory's performance and status in this programme were considered on a case-by-case basis (Table 4).

Establishing quality systems in veterinary testing laboratories

Based on the achievements of the EQAP, IAEA's Department of Technical Cooperation embarked on an interregional project to assist 15 veterinary testing laboratories in establishing quality systems. This included workshops, provision of reference materials, expert visits, and the development and use of standardized training documents, e.g. "Guidelines for Establishing Quality Systems in Veterinary Diagnostic Testing Laboratories" [28] (http://www.iaea.org/programmes/nafa/d3/public/guidelines.pdf). These guidelines provide crucial information to assist veterinary testing laboratories to develop and implement a quality system based on the OIE Standard "Management and Technical Requirements for Laboratories Conducting Tests for Infectious Animal Diseases" [5]. Furthermore it gives an example-oriented overview of the structure and contents of critical documents and procedures such as Quality Manual, Standard Operating Procedures, etc. inherent to a quality system and describes the different stages in the implementation of the OIE Standard. For that reason it can be used as a practical guide for the production of necessary documents but also as a help to determine the status of a laboratory during its "journey" towards establishing a quality system.

Acknowledgments The authors wish to thank participants from Southeast Asia, Africa, and Latin America for their contributions and kind support in producing and returning results. We are grateful for the substantial inputs for establishing and modernizing the EQAP especially during three consultants meetings in 1994, 1998, and 2000, in particular to Barbara van der Eerden, Camille Ooijen, Peter Wright, John Gilmore, Jim Pearson, Steve Edwards, Richard Jacobson, William Doughty, Ian Gumm, and Brigitte Thoms. We would like to express our gratitude to John Anderson and his colleagues from the Institute for Animal Health, Pirbright, UK, for the supply of FMD and Rinderpest proficiency testing round samples and the staff from the FAO/IAEA Animal Production and Health Subprogramme for continued advice, discussion and support, especially to Dierk Rebeski and Eva Winger for supplying test samples for the trypanosomosis ELISAs and to John Crowther, Mario Garcia, and Ales Fajgelj for discussions and advice regarding the selection of samples and analysis of data.

References

1. Robinson MM, Jeggo MH (1998) Veterinary diagnostic laboratories in developing countries: the challenge of credibility. Rev sci tech Off int Epiz 17(2):454–458
2. Caporale V, Nannini D, Ricci L (1998) Quality assurance in veterinary diagnostic laboratories. Rev sci tech Off int Epiz 17(2):459–468
3. AS ISO/IEC 17025–2005 General requirements for the competence of testing and calibration laboratories, 2005
4. Organization for Economic Cooperation and Development (1998) OECD Principles of good laboratory practice (1997 revision) OECD, Paris
5. OIE (2002) OIE quality standard and guidelines for veterinary laboratories: infectious diseases. Office international des epizooties, 12 Rue de Prony, 75017 Paris, France, ISBN 92-9044-575-0
6. Jacobson RH (1998) Validation of serological assays for diagnosis of infectious diseases. Rev sci tech Off int Epiz 17(2):469–486
7. Wright PF et al (1993) Standardization and validation of enzyme linked immunosorbent assay techniques for the detection of antibody in infectious disease diagnosis. Rev sci tech Off int Epiz 12(2):435–450
8. Crowther JR, Unger H, Viljoen GJ (2006) Aspects of kit validation for tests used for the diagnosis and surveillance of livestock diseases; producer and end-user responsibilities. Rev sci tech Off Int Epiz 25(3):913–935
9. IAEA (1994) Establishment of external quality assurance procedures for use with FAO/IAEA ELISA kits: Report of an FAO/IAEA Consultants Meeting, IAEA, FAO/IAEA Animal Production and Health Subprogramme, Vienna, 12–16 September 1994

10. van der Eerden BJM, (1997) The FAO/IAEA External Quality Assurance Programme for Disease Diagnosis 319–338, Towards livestock disease diagnosis and control in the 21st Century, Proceedings of a symposium, Vienna 7–11 April 1997, IAEA-SM-348/24, 1997
11. van der Eerden BJM (1995) The External Quality Assurance Programme for use with the FAO/IAEA Rinderpest Competitive ELISA: Interim report 1995. IAEA, FAO/IAEA Animal Production and Health Subprogramme, Vienna, 1996
12. The External Quality Assurance Programme for use with the FAO/IAEA Rinderpest Competitive ELISA: Interim Report (EQA/RP/1996A). IAEA, FAO/IAEA Animal Production and Health Subprogramme, Vienna, 1997
13. Colling A, Louvandini H (1997) The External Quality Assurance Programme for use with the FAO/IAEA Rinderpest Competitive ELISA: Interim Report (EQA/RP/1997A). IAEA, FAO/IAEA Animal Production and Health Subprogramme, Vienna, 1998
14. Colling A, Louvandini H (1998) The External Quality Assurance Programme for use with the FAO/IAEA Rinderpest Competitive ELISA: Interim Report (EQA/RP/1998A). IAEA, FAO/IAEA Animal Production and Health Subprogramme, Vienna, 1999
15. van der Eerden BJM (1995) The External Quality Assurance Programme for use with the FAO/IAEA *Brucella abortus* indirect ELISA: interim report 1995 BRA/a. IAEA, FAO/IAEA Animal Production and Health Subprogramme, Vienna, 1996
16. IAEA (1996) The External Quality Assurance Programme for use with the FAO/IAEA *Brucella abortus* indirect ELISA: interim Report (EQA/BRA/1996A). IAEA, FAO/IAEA Animal Production and Health Subprogramme, Vienna, 1997
17. Colling A, Louvandini H (1997) The External Quality Assurance Programme for use with the FAO/IAEA *Brucella abortus* indirect ELISA: interim report (EQA/BRA/1997A). IAEA, FAO/IAEA Animal Production and Health Subprogramme, Vienna, 1998
18. Colling A, Louvandini H (1998) The External Quality Assurance Programme for use with the FAO/IAEA *Brucella abortus* indirect ELISA: interim report (EQA/BRA/1998A). IAEA, FAO/IAEA Animal Production and Health Subprogramme, Vienna, 1999
19. Colling A, Louvandini H (1999) The External Quality Assurance Programme for use with the FAO/IAEA *Brucella abortus* indirect ELISA: interim report (EQA/BRA/1998B). IAEA, FAO/IAEA Animal Production and Health Subprogramme, Vienna, 1999
20. Colling A, (1999) The External Quality Assurance Programme for use with the FAO/IAEA *Brucella abortus* indirect ELISA: interim report (EQA/BRA/1999A). IAEA, FAO/IAEA Animal Production and Health Subprogramme, Vienna, 2000
21. Colling A, Louvandini H (2000) The External Quality Assurance Programme for use with the FAO/IAEA *Brucella abortus* indirect ELISA: interim report (EQA/BRA/1999B). IAEA, FAO/IAEA Animal Production and Health Subprogramme, Vienna, 2000
22. van der Eerden BJM (1996) The External Quality Assurance Programme for use with the FAO/IAEA trypanosomosis direct sandwich ELISA for the detection of antigens of *T. brucei*, *T. congolense*, and *T. vivax* (EQA round 1996 TRYP/a) interim report 1996. IAEA, FAO/IAEA Animal Production and Health Subprogramme, Vienna, 1997
23. Rebeski DE, Winger EM, Lelenta M, Colling A, Robinson MM, Ndamkou Ndamkou C, Aigner H, Dwinger RH, Crowther JR (1999) Comparison of precoated and freshly coated microtitre plates using denatured antigen for the detection of antibodies against *Trypanosoma congolense* by indirect enzyme-linked immunosorbent assay. Animal Health and Production for Development. Proc. 9th Conf. Inst. Trop. Vet. Med. Harare, Zimbabwe, 1998
24. Colling A (1998) The External Quality Assurance Programme for use with the FAO/IAEA FMD LPB-Antibody ELISA: interim report (EQA/FMD/1998A). IAEA, FAO/IAEA Animal Production and Health Subprogramme, Vienna, 1999
25. Colling A (2000) The external quality assurance programme (EQAP) for the FAO/IAEA antibody FMD ELISA in Southeast Asia, use of immunoassay technologies for the diagnosis and control of foot-and-mouth disease in Southeast Asia, IAEA Tecdoc-1150, 2000
26. Gall D, Colling A, Marino O, Moreno E, Nielsen K, Perez B, Samartino L (1998) Enzyme immunoassays for serological diagnosis of bovine brucellosis: a trial in Latin America, Clinical and Diagnostic Laboratory Immunology, Sept 1998, pp 654–661
27. The FAO/IAEA External Quality Assurance Programme (EQAP) and movement towards a generic veterinary diagnostic testing laboratory accreditation scheme. Report of an FAO/IAEA Consultants Meeting organized by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture and the FAO/IAEA Agriculture and Biotechnology Laboratory Vienna International Centre, 2–6 February 1998
28. Guidelines for Establishing Quality Systems in Veterinary Diagnostic Testing Laboratories Report of an Joint FAO/IAEA Consultants Meeting/Work shop organized by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, FAO/IAEA Agriculture and Biotechnology Laboratory and Department for Technical Co-operation Vienna International Centre, 4–8 September 2000